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The Influence of Invasive Plants on the Small Mammal Community in a Cold Desert

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THE INFLUENCE OF INVASIVE PLANTS ON THE SMALL MAMMAL COMMUNITY IN A COLD DESERT

by

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ABSTRACT

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Exotic invasive species can alter ecosystem health. Cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola kali*) and tall tumble mustard (*Sisymbrium altissimum*) are widely distributed invasive plants occurring throughout desert and shrub-steppe communities in the western United States. Due to the relative ease of capture, small mammal community metrics are often used to quantify overall ecosystem health. Studies examining small mammal communities are numerous but few have specifically examined the effects of invasive plants at the community level in arid ecosystems. In this study I examined community level small mammal responses to changes in microhabitat features, with an emphasis on levels of invasive species dominance. In the summers of 2010-2013, small mammals were sampled using Sherman live traps and vegetation structure was measured using the line-point intercept method. Using estimates of species richness and number of captures (relative abundance), I developed generalized linear mixed models (GLMMs) to test the predictor variables: percent invasive species cover, plant species richness, percent shrub cover, percent bare ground, mean plant height, moon illumination, and percent litter cover. Findings revealed a significant negative relationship between percent invasive species cover and small mammal species richness and a significant

nonlinear relationship between percent invasive species cover and small mammal relative abundance, where total capture rates and cover of invasive plants exhibited a positive relationship, reached a threshold, and then exhibited a negative relationship. This non-linear finding provides support for the intermediate disturbance hypothesis and suggests that intermediate levels of exotic plant invasions may positively affect organisms that are members of higher trophic levels that consume primarily small mammals. Overall, this study suggests that if maintaining high levels of total small mammal abundance (e.g., biomass) is important for higher trophic level species (e.g., the kit fox), the importance of invasive species eradication and native species restoration should be carefully considered if invasive species have not completely displaced the native flora community. However, if maintaining small mammal diversity is a higher priority, eradication of invasives and native species restoration should be a top priority. Further, maintaining intermediate levels of invasive species in order to strengthen small mammal biomass could prove both challenging and risky.

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INTRODUCTION

Ecosystems health is often assessed by community metrics at differing clades and trophic levels (e.g., native insect species richness, native small mammal total abundance) (Tilman et al 1999, Niemi and McDonald 2004, Balvanera et al. 2014). As invasive plant species colonize native vegetation communities, communities occurring within ecosystems can be dramatically modified and the functionality of ecosystem services can be reduced (Tilman et al 1999, Reisner et al. 2013). Invasive plant species encroachments have been found to change vegetative composition (Knapp 1996), decrease richness of plant species (Hejda et al 2009), reduce functional plant diversity (Hejda et al. 2009), and reduce total abundance of plants (Freeman et al. 2014). Additionally, plant invasions can lead to changes in species community composition at higher trophic levels (Ostoja and Schupp 2009, Fischer et al. 2012, Freeman et al. 2014). On the other hand, exotic plant invasions have been found to have positive effects on some species. For example, some nesting bird species positively respond to saltcedar (*Tamarix ramosissima)* invasion (MacGregor-Fors et al. 2013). Gaining more knowledge on the effects of biological invasions on animal communities is vital to decisions concerning wide-scale management actions, especially as exotic species continue to successfully invade ecosystems and are forecasted to increase (Sax et al. 2007).

Arid shrublands and grasslands throughout the western United States have been particularly impacted by invasive species, as grazing and fire regime changes have allowed establishment of annual grass species such as cheatgrass (*Bromus tectorum*), medusahead (*Taenatherum caput-medusa*), and red brome (*Bromus rubens*) (Knapp 1996, Chambers 2008). Of the annual grass species, cheatgrass has been a particularly successful invader in the western United States. Since introduction in the early 1900s, the grass has been able to dominate due to its ability to saturate the understory and can create continuous monocultures (Young et al. 1987).

These monocultures act as ideal fuel and increase the frequency of fire and perpetuate further establishment (Reisner et al 2013). Exotic forbs such as Russian thistle (*Salsola kali*) and tall tumble mustard (*Sisymbrium altissimum*) are also widely distributed in shrublands (Yensen 1981). Commonly known as tumbleweeds, the prolific seeding habits of these forbs make them successful invaders, especially in previously disturbed sites (Yensen 1981). The combined invasion of the aforementioned species is responsible for the elimination of large amounts of sagebrush-bunchgrass habitat (Yensen 1981, Knapp 1996, Chambers 2008, Reisner et al. 2013).

Plant invasion, especially the establishment of annual grasses, can cause cascading effects (Ostoja and Schupp 2009, Freeman et al. 2014). Monocultures often alter the physical habitat (Knapp 1996) and forage structure for small mammals (Reisner et al. 2013). This reduction in habitat and forage can cause a bottom-up effect, lowering animal diversity and abundance at higher trophic levels (Knapp 1996, Ostoja and Schupp 2009, Freeman et al. 2014, Zeng et. al. 2014). Other investigations have shown that plant invasions can increase avian diversity (Fischer et al. 2012) and small mammal abundance (Malick et al. 2012). Less is known of the impacts of invasive species on predator-prey interactions and competition. For example, relaxed competition resulting from declines in species richness may shift community assemblages, allowing remaining species to better utilize the resources and habitat characteristics provided by invasive species (Kelt 2011).

Due to the high cost and intensity of monitoring animal populations residing at high trophic levels, small mammal studies are used as a key tool in quantifying overall ecosystem health. This clade is relatively easy to capture and quantify, has a large influence on the distribution of plants, and acts as a pivotal food source for mammalian and avian predators (Sieg 1987, Kelt 2011). As a primarily granivorous guild, desert small mammals are influenced by the changing seed composition (Freeman et al. 2014). In addition to acting as prey species, small mammals can maintain plant diversity (Olff and Ritchie 1998). Researchers have found that encroachment of invasive plant species lowers the diversity of small mammal species and can reduce abundance of particular species, which can impact plant species richness due to decreased seed dispersal (Hanser and Huntly 2006, Ostoja and Schupp 2009, Hall 2012).

Small mammal communities are influenced by a host of factors. Diverse communities have been observed in areas with high levels of structural heterogeneity (Ostoja and Schupp 2009, Hall 2012, Thompson and Gese 2013). Small mammal species and communities tend to have higher richness in areas with less dense groundcover, and have been found to prefer mosaic type plant communities (Thompson and Gese 2013). This causes concern in invaded systems as heterogeneity is usually reduced by plant invasions (Reisner et al. 2013). Studies looking specifically at cheatgrass invasion have found similar results across desert systems. A recent study across the Great Basin found that community abundance and richness decreased linearly with increasing cheatgrass cover, though community abundance appeared to be driven by the most ubiquitous species, the deer mouse (*Peromyscus maniulatus*) (Freeman et al. 2014). Similarly, Hall (2012) observed a negative linear relationship between cheatgrass density and abundance of North American deer mouse, but the impacts of cheatgrass on community abundance was not recorded .Others have suggested that the magnitude of cheatgrass invasion on small mammal total abundance is species-dependent (Ostoja and Schupp 2009).

Recent research has begun to challenge the widely held viewpoint that invasive species invasions ubiquitousiy lead to reduced abundance of native animal populations. The intermediate disturbance hypothesis has been used to explain observations of increasing overall abundance following a moderate level of disturbance (Roxburgh et al. 2004). A wide variety of small animal communities have been found to respond in accordance with the intermediate disturbance hypothesis. Riparian bird communities have been found to respond positively to Russian olive invasion, up to a threshold (Fischer et al. 2012). Reptile communities also responded with increased total abundance following logging, with the highest abundance found around a median time since disturbance (Hu et al. 2013). Studies addressing this topic for small mammal species and communities are sparse and mixed. Freeman et al. (2014) found that small mammal abundance decreased with increasing cheatgrass cover. Conversely, a study on the influence of spotted knapweed (*Centaurea stoebe*) on the small mammal community (primarily deer mouse) found that invasion had a positive influence on small mammal abundance (Malick et al. 2012). These findings suggest that further examination on the impact of plant invasions on small mammal communities should be undertaken.

The overall objective of this study was to help elucidate the role of invasive plant species on small mammal communities. Specifically, I aimed to determine 1) the impact of invasive plant species on small mammal diversity (species richness), and 2) the impact of invasive plant species on small mammal productivity (relative abundance).

METHODS

Study Area and Site Selection

Sampling of small mammal and plant communities was conducted throughout the summers of 2010 through 2013 on 166 km^2 of the eastern portion of the U.S Army Dugway Proving Ground (DPG) located approximately 128 km southwest of Salt Lake City, in Tooele County, Utah, USA (Figure 1). Elevations ranged from 1349 m to 2021 m. The area is characterized as a cold desert: winters are cold, summers are hot and dry, with the majority of precipitation occurring in the spring. Average maximum temperatures on DPG range from 3.3°C in January to 34.7°C in July (Arjo et al. 2007). Average minimum temperatures range from –8.8°C in January to 16.3°C in July. Mean annual precipitation is 20.07 cm. The study area consisted of a predominately flat playa punctuated with steep mountain ranges. The lowest areas consisted of sparsely vegetated salt playa flats. Slightly higher elevation areas were less salty and supported a cold desert chenopod shrub community dominated by greasewood (*Sarcobatus vermiculatus*). Higher elevations consisted of vegetated sand dunes. Near the bases of the higher steep mountains were shrub steppe communities of big sagebrush (*Artemisia tridentata*). The highest elevation was a Utah juniper (*Juniperus osteosperma*) community including black sagebrush (*Artemisia nova*) and bluebunch wheatgrass (*Elymus spicatus*). Where wildfires had occurred, monocultures of cheatgrass (*Bromus tectorum*), tall tumble-mustard (*Sisymbrium altissimum*), and Russian thistle (*Salsola kali*) were common. The aforementioned exotic species were also interspersed within communities of sagebrush, rabbitbrush (*Chrysothamnus* sp.) and juniper (Arjo et al. 2007).

Data Collection

We used stratified-random sampling to establish sixteen 50m x 50m sampling plots throughout the study area (Figure 1). We evaluated vegetation composition and structure using five 50-m line transects following the axis of the plot and spaced 10 m apart. Using the line-point intercept method (Herrick et al. 2005), we measured plant species and height at 1-m intervals. We sampled vegetation on plots twice per summer the day prior to the onset of small mammal sampling. All plant species were identified to species. Parameters estimated from transects were percent bare ground, percent litter cover, mean plant height, percent shrub cover, and percent invasive species cover. Percent cover of invasive species was determined by using the combined instances of occurrence for cheatgrass, tall tumble-mustard, and Russian thistle.

Small mammals were sampled at each site for four consecutive nights (i.e., one trapping session). Two trapping sessions took place each summer, with one in early summer (May 1 to June 30) and the other in late summer (August 1 to September 30). We established a 7 x 7 trapping grid (8.3 m spacing per trap) with Sherman live traps (Sherman Traps, Inc., Tallahassee, FL, USA) at each site. Traps were baited with a mixture of black sunflower and mixed bird seed. All captured small mammals were identified to species and standard morphometric measurements (e.g., mass, tail length, hind foot length) taken. Moon brightness was recorded for each trapping session as the mean moon illumination of the four trapping nights. Species richness was estimated for all small mammal plots using the maximum number of species encountered during a given trapping session. Small mammal abundance was estimated by using the average number of nightly captures per session/grid, a metric often used as a surrogate of true abundance for small mammals (Thompson 2012, Upham and Hafner 2013, Freeman et al. 2014). Capture and handling protocols were reviewed and approved by the Institutional Animal Care and Use Committees (IACUC) at the United States Department of Agriculture's National Wildlife Research Center (QA-1734) and Utah State University (#1438). Permits to capture and handle small mammals were obtained from the Utah Division of Wildlife Resources (COR #4COLL8322).

Data Analyses

The effects of predictor variables (percent invasive species cover, plant species richness, percent shrub cover, percent bare ground, mean plant height, moon illumination, and percent litter cover) on small mammal community metrics (small mammal richness and relative abundance) were assessed using generalized linear mixed models (GLMMs) from the GLIMMIX procedure in SAS/STAT 13.2 in the SAS® System for Windows 9.4 TS1M2 (McCulloch and

Neuhaus, 2005, SAS Institute Inc. 2013). Plot was used as the sampling unit for analysis, with 16 independent replications.

Because the same 16 plots were sampled over time, plot was fit as a random effect in all models. We checked continuous variables for collinearity using correlational analysis (we eliminated any one of a pair of variables with Pearson r indicating more than 30% correlation using a ranking of importance to research questions). Mean plant height, percent shrub cover, and percent litter cover were square-root transformed to improve normality. Small mammal richness and small mammal abundance were included as continuous response variables in separate models, and the vegetation parameters (invasive cover, mean plant height, shrub cover, moon illumination, litter cover and plant richness) were included as continuous predictor variables. Both models used a log-normal distribution. Effects of predictor variables were considered significant at a probability of $P < 0.05$. Because the predictor variable invasive cover was of primary interest I tested for a non-linear relationship between response variables and invasive cover by including a quadratic (invasive cover x invasive cover interaction) term (Zar 2009) if invasive cover alone was not significant.

RESULTS

Between May 2010 and September 2013 we conducted nine trapping sessions and accumulated 4987 small mammal captures over 28,224 trap nights. A total of 12 unique species were captured. In decreasing order of abundance, the following species were captured: Ord's kangaroo rat (*Dipodomys ordii,* 70.3%) , deer mouse *(Peromyscus maniculatus*, 15.6%), chisel-toothed kangaroo rat (*Dipodomys microps,* 5.9%*)*, long-tailed pocket mouse (*Chaetodipus formosus,* 3.2%), northern grasshopper mouse (*Onychomys leucogaster,* 1.9%), western harvest mouse (*Reithrodontomys megalotis*, 1.4%), Great Basin pocket mouse (*Perognathus parvus*

0.8%), desert woodrat (*Neotoma lepida*, 0.2%), piñon mouse (*Peromyscus truei*, 0.1%), antelope ground squirrel (*Ammospermophilus leucurus*, 0.1%), sagebrush vole (*Lemmiscus curtatus*, <0.1%), and little pocket mouse (*Perognathus longimembris*, <0.1%).There was an average of 8.8 nightly captures per plot, ranging from 0-29 captures. Plot richness ranged from 0-8 with a mean richness of 2.6.

We detected 119 unique plant species across the 16 plot locations. The percentage of invasive cover at these sites ranged from 3 to 99% with an average invasiveness of 48.8% (SD=29.27). In decreasing order of abundance the following invasive species were encountered: cheatgrass (*Bromus tectorum*, 59.5%), tall tumble mustard (*Sisymbrium altissimum* 6.97%), and Russian thistle (*Salsola kali*, 5.02%). The most commonly encountered non-invasive species were big sagebrush (*Artemesia tridentata*, 7.48%), *Poa* spp. (2.93%), and Indian rice grass (*Achnatherum hymenoides*, 1.9%). Thus, the three invasive species comprised the 1st, 2nd, and 4th most commonly observed species during the study.

Percent bare ground and grass cover were removed from models due to collinearity (Figure 2). Moon brightness ($p = 0.045$, $df = 126$) and percent invasive cover ($p = 0.011$, $df = 126$) (Figure 3) were found to be the significant drivers of decline in small mammal richness (Table 1). There was some evidence that small mammal richness was influenced by mean plant height ($p = 0.053$, $df = 126$) and percent shrub cover ($p = 0.053$, $df = 126$) (Table1), though these relationships were not significant. Other vegetation structure parameters were insignificant (Table 1). We found evidence of a non-linear relationship between percent invasive cover and small mammal relative abundance ($p < 0.001$, $df = 126$) (Table 2, Figure 4). Moon illumination was a significant predictor of small mammal relative abundance and exhibited a negative relationship ($p = 0.0085$, df =126) (Table 2). Other vegetation parameters were insignificant in the model (Table 2).

DISCUSSION

Exotic invasion of cheatgrass, Russian thistle and tall-tumble mustard had a significant influence on species richness, where increasing percent cover of invasive species appeared to cause a decrease in the species richness of the small mammal community (Figure 3). These changes likely resulted from a change in structural composition and a decrease in habitat suitability, such as decreased openness and reduced shrub cover (Ostoja and Schupp 2009). Researchers have consistently found that small mammal richness decreases with increasing cheatgrass cover throughout the Great Basin (Ostoja and Schupp 2009, Hall 2012, Freeman et al 2014); however, the effects of forbs such as Russian thistle and tall-tumble mustard have not been examined as thoroughly. Although these invasive forbs likely provide temporary cover for small mammals, this study suggests that they do not prove to be a substitute for native sagebrush-bunchgrass habitat. At higher levels of invasive cover, the plots largely consisted of cheatgrass monocultures which reduce habitat quality for all small mammal species (Ostoja and Schupp 2009, Rieder et al 2010, Hall 2012). Quadrupeds, such as deer mice, have been found to have their sprint velocity hindered by the increases in cheatgrass cover (Rieder et al 2010). Ord's kangaroo rat is also hindered by cheatgrass monocultures, but to a lesser extent at low cheatgrass densities (Reider et al. 2010). Forage availability was likely adversely affected by exotic invasion as well. Kangaroo rats are able to consume and cache cheatgrass seeds, where other small mammals do not gain the needed calories and protein from this species (Kelrick et al 1986, Jenkins and Breck 1998). Invaded sites featured reduced forage availability and habitat for the species (Knapp 1996, Ostoja and Schupp 2009). These results align with the findings of prior studies throughout the Great Basin and this structural change likely caused a change in niche space and resource availability for species to cohabitate (Thompson and Gese 2013).

In addition to invasive cover causing a significant decrease in species richness, there was some evidence supporting that plant height and percent shrub cover also have an impact on total species richness. Thompson and Gese (2013) linked landscape heterogeneity to community richness and found that plant height positively influenced small mammal richness. Many quadrupeds prefer to forage in areas that have cover, which is found in areas with a higher plant height (Freeman et al. 2014). Further, the most abundant species, Ord's kangaroo rat, prefer to forage in areas with less shrub cover whereas other species generally forage under shrub cover (Freeman et al. 2014). The decrease in species richness was likely driven by the changes caused by exotic invasion, including decreased cover (Knapp 1996), reduced heterogeneity (Thompson and Gese 2013) and reduced niche space for the less abundant species (Freeman et al 2014).

We found evidence of a non-linear relationship between invasive species and small mammal relative abundance. Specifically, small mammal abundance increased with increasing levels of invasive until a threshold was reached at about 48% invasive cover, after which abundance began to decrease (Figure 4). This provides evidence that small mammal abundance in our study area increases with moderate levels of "disturbance." This intermediate disturbance hypothesis effect is commonly observed in bird communities (Fischer et al. 2012); however, it has been rarely observed in small mammal communities. This increase was likely due to the most abundant species, Ord's kangaroo rat. As exotic invasion occurs, more inter-shrub space is created, which is commonly used more frequently by bipeds (Thompson 1982, Freeman et al. 2014). We speculate that a larger niche for Ord's kangaroo rat was created as shrub cover decreased with invasion and other small mammal species experienced reduced abundance or local extirpation. Ord' kangaroo rat also prefers areas with sparse litter availability which supports litter acting as a marginal predictor of abundance (Thompson and Gese 2012). It has been suggested that the relationship between litter and abundance is driven by a change in energetics. With increasing litter present, species are required to forage in an increasingly three-dimensional environment (Thomson and Gese 2012). We speculate that our observed relationship is driven by creation of a larger niche for Ord's kangaroo rat as other small mammal species experience reduced abundance or local extirpation as invasive plants become more dominant.

The subsequent decrease in small mammal abundance following a threshold of disturbance was likely caused by the decreases in forage availability and obstruction of movement for all species. As cheatgrass forms monocultures, Ord's kangaroo rat has been found to have a reduced sprint velocity and hindered locomotion (Reider et al. 2009). Forage reduction likely became too prominent for the Ord's kangaroo rat to handle, as the energetic demands were not completely met by the nutrient poor cheatgrass seeds (Kelrick et al 1986, Jenkins and Breck 1998).

Our study indicates that exotic invasions have somewhat differential impacts on small mammal community metrics. Freeman et al. (2014) reported similar findings as ours for species richness, but observed a linear negative relationship for relative abundance, where we found evidence of an optimum threshold. Our results suggest an intermediate response of the community to exotic invasion when Ord's kangaroo rat is the dominant species. Plot biomass was highly correlated to relative abundance (Figure 5). As such, the amount of prey base available to higher trophic level organisms that regularly consume Ord's kangaroo rats, like the kit fox (Kozlowski et al. 2008) may be at a peak in areas that have been moderately disturbed by invasive plant species. If maintaining high levels of total small mammal abundance (i.e., biomass) of the small mammal community is important for higher trophic level species (i.e., the kit fox), the importance of invasive species eradication and native species restoration should be carefully considered in areas where kangaroo rats are or have the potential to be the most abundant small mammal. However, if maintaining small mammal diversity is a higher priority for an agency, invasive species eradication and native species restoration should be a priority. Further, due to the tendency of cheatgrass encroachments to increase the frequency of fire disturbance and engender cheatgrass monocultures, it is unlikely that an intermediately disturbed community could be maintained without intensive management efforts.

REFLECTION

Throughout my undergraduate career I have benefitted greatly from my experiences gained from participating in research. This project in particular has challenged my critical thinking skills in ways that I did not anticipate. I have benefitted from the entire process including the tedium of data refinement, analysis and manuscript preparation. Throughout the process, mentorship along the way has proved to be specifically helpful.

I started working on this project during the spring of 2014. I came across this project when Bryan sent an email to wildlife students looking for interested students. I decided to use some of the data for my thesis. The data was collected for this project prior to my work on it, and the data set was very robust. The first challenge of this project was to define a specific research question. After working with Bryan to determine a research question, the data processing phase started.

I found the data processing phase to be the most tedious section of the project. My data set spanned multiple years and sample sessions and I did not anticipate the time that it would take to complete this process. This process took several months to complete. Throughout this process, I found that it was easier to set specific work time and collect all possible variables that could be used to answer the research questions of the study. It was easier to summarize all possible data as I went, instead of backtracking to use specific data.

Following the data processing phase, my project moved onto the analysis phase. This part of the project required me to refine my research questions, because it was not possible to specifically answer all of the questions that could be asked. Much of this part of the project was higher than my statistical knowledge and it required guidance from Bryan and Susan Durham. The analysis phase and development of models to answer my questions was a difficult stage of the project. Many of the statistics used in this thesis were well above the knowledge that I learned in introductory statistics classes. Because of this, I was required to look for sources to further explain the statistics and help me to grasp understanding of the results. I found that the best resource to interpret what my analysis meant was to look at other ecology articles that used the same form of analysis. Once doing this, it was a lot easier to understand the implications of my results and formulate a story to tell with my research

The manuscript phase required a depth of knowledge that was dramatically different than anything that I had previously written. Literature review and discovery of sources was invaluable for determining how to structure my thesis. Further, I found that the style of writing was different than what I was used to for reports. Determining tone for the paper was more difficult than I anticipated. Once I figured this out, it was much easier to articulate ideas for my manuscript. Throughout the manuscript process, I needed several drafts before I was comfortable with my work. I did not think that it would take nearly as much refinement as it did, but this process allowed me to turn in high quality work.

Overall the most valuable part of this project was articulating my research to peers. I was able to attend the Utah Chapter of the Wildlife Society Annual meeting (UTTWS), as well as the USU Student Research Symposium and National Conference for Undergraduate Research (NCUR). For each conference I had to articulate my findings differently. At the UTTWS meeting, I was able to talk to peers about the ecological implications with a more in-depth approach. I gained valuable insight from peers about the implications of my research and was able to use this feedback for my manuscript. At the other conferences, I was required to step back and talk about the big picture of my research. At NCUR, I was able to describe my research to people from varied disciplines and from around the country. This was unique, because I was able to communicate the problem of exotic invasions in the western United States. Communicating this was valuable, because it allowed me to talk about my research in a more accessible way.

I was fortunate enough to be awarded funding for my project by the QCNR (Undergraduate Research Grant) and USU Office of Research and Graduate Studies (URCO). This helped considerably, because I was able to go through the funding proposal phase. This was valuable for future graduate school purposes and allowed me to reduce my outside work hours as I worked to complete my thesis. Both Bryan and Eric severed as reviewers and editors of my proposal.

Throughout the entire process I have gained an understanding for the inner workings of research. Although I was not involved directly in the design and data collection phases of the study, it was valuable to go through the process of data collection, analysis and synthesis. I am overall happy with my research experience and it will be a valuable reference point for graduate and other research work in the future. I appreciated the mentorship that was provided throughout the process, and the opportunities that I was provided by the Honors Program. My only regret is that I didn't start undergraduate research earlier. If I would have started before my junior year, I would have likely been able to develop a more extensive project, and be more involved in the experimental design and collection phase. I recommend undergraduate research to anyone that is considering it and hope that it is an equally valuable experience for incoming students.

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TABLES AND FIGURES

Table 1: Results of GLMM of predictor variables against small mammal richness.

Small Mammal Richness GLMM					
Predictor Variable	Estimate	SE	DF	T value	P
Mean Plant Height	0.06923	0.0354	106	1.96	0.053
Percent Invasive	-0.00605	0.0023	83.92	-2.60	0.011
Percent Shrubs	0.07645	0.0386	58.16	1.98	0.053
Percent Moon Illumination	-0.1992	0.0983	124.9	-2.03	0.045
Percent Litter	0.0129	0.0139	129.6	0.93	0.354
Plant Richness	0.001698	0.0128	85.26	0.13	0.89

Table 2: Results of GLMM of predictor variables against small mammal relative abundance.

Small Mammal Relative Abundance (# of nightly captures) GLMM					
Predictor Variable	Estimate	SE	DF	T value	P
Mean Plant Height	-0.013	0.097	127.9	-0.13	0.893
Percent Invasive	-0.005	0.006	122.2	-0.84	0.402
Percent Invasive (quadratic)	-0.0007	0.00017	106	-4.07	<0.0001
Percent Shrubs	0.063	0.115	65.65	0.55	0.585
Percent Moon Illumination	-0.663	0.248	119.5	-2.67	0.0085
Percent Litter	0.004	0.003	123.9	1.41	0.16
Plant Richness	-0.002	0.036	112	-0.06	0.953

Figure 1. Study Area. Study plot locations at Dugway Proving Ground, Tooele County, UT. Dugway is predominately a flat playa with steep mountain ranges, with a cold desert climate pattern. X's denote the locations of sixteen 50m X 50m trapping plots. Plots were sampled twice per summer for four years. Vegetation measurements were taken during every trapping session.

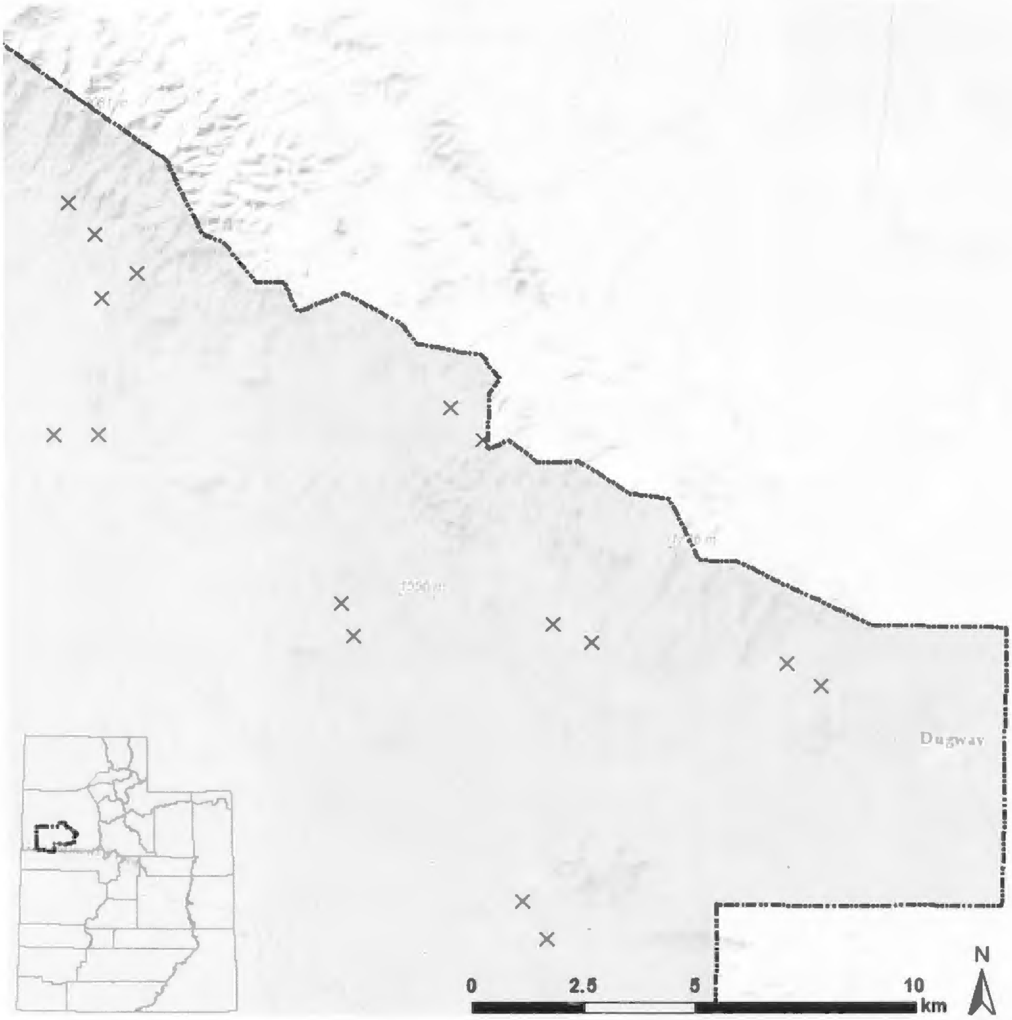


Figure 2: Plot of correlation between bare ground and invasive species cover.

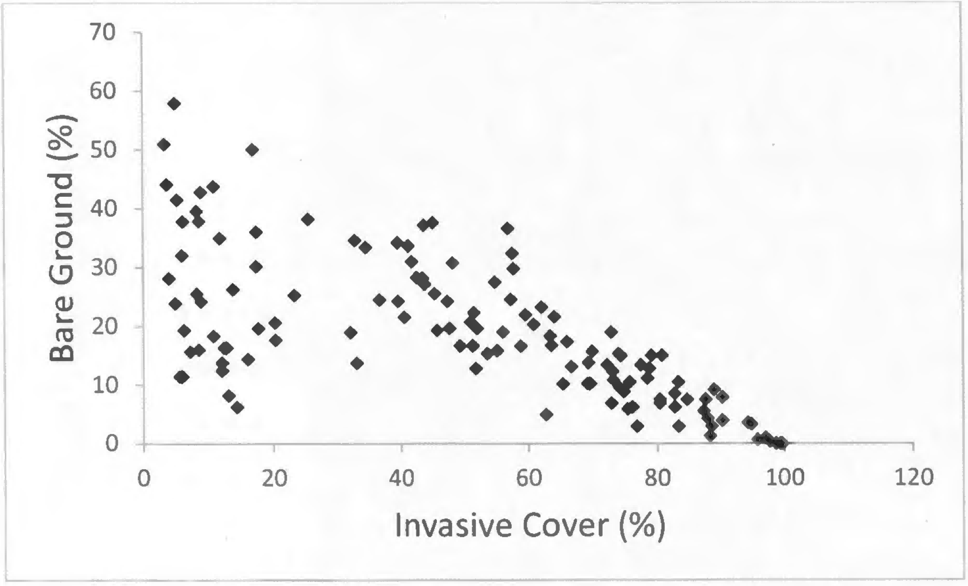


Figure 3: Plot of correlation between small mammal richness and invasive cover (n=143).

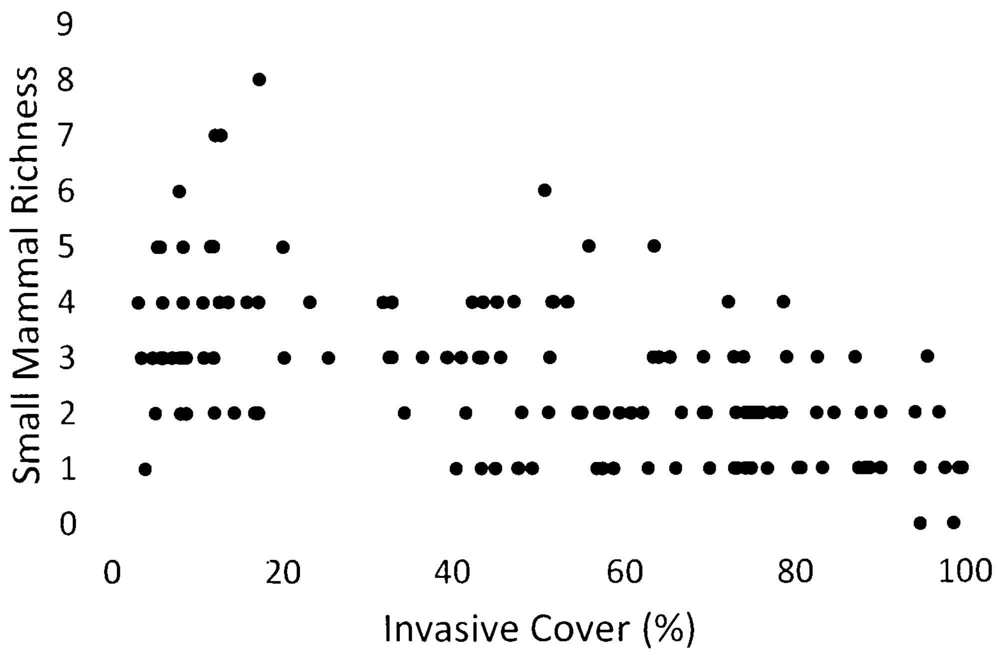


Figure 4: Plot of nonlinear correlation between small mammal relative abundance and invasive cover (n=143).

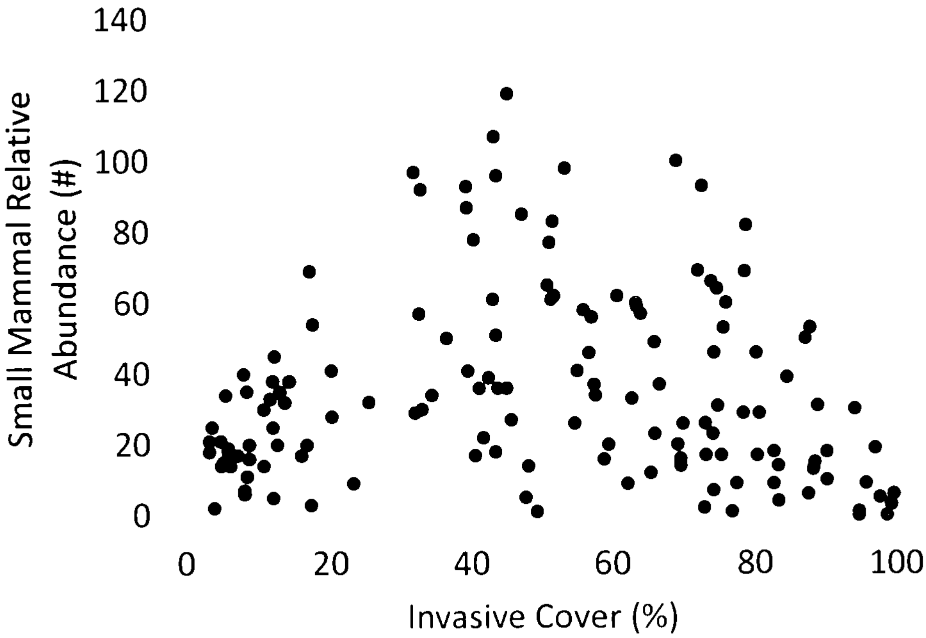
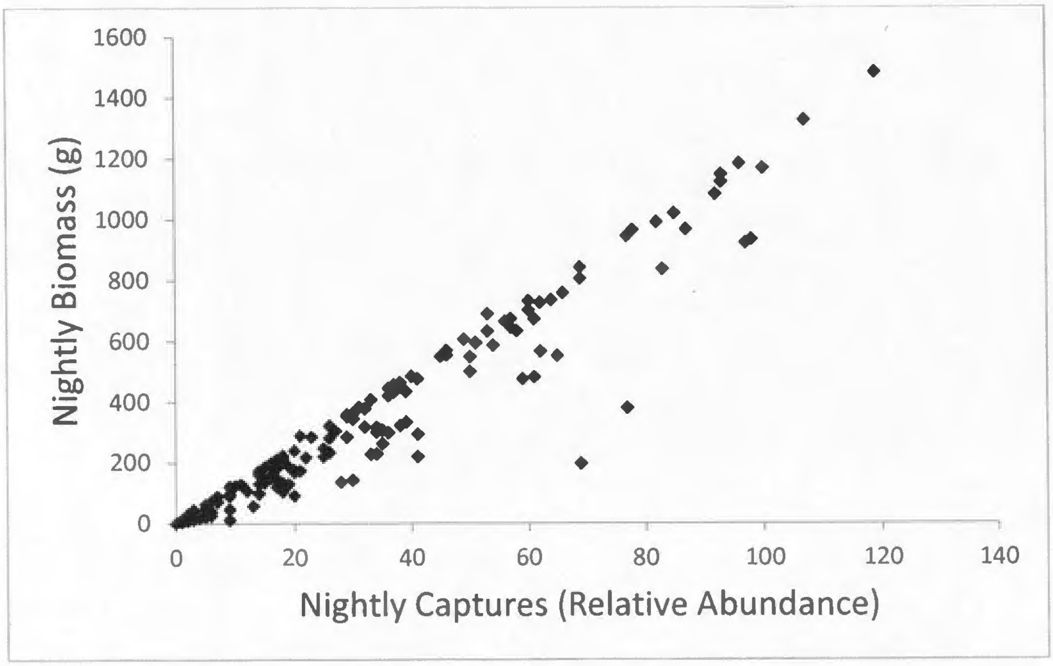


Figure 5: Plot of correlation between nightly biomass and nightly captures.



AUTHOR BIOGRAPHY

Trinity N. Smith was born and raised in West Wendover, Nevada and graduated from West Wendover High School in 2011. Trinity expects to graduate in May 2015 from Utah State University (USU) with a B.S. in Wildlife Science, minors in Fisheries Science and Biology, and Departmental Honors with Honors in University Studies. During her undergraduate career, Trinity served as a Research Assistant, Honors Peer Mentor, and Academic Adviser. Trinity also served as a member of USU's student chapter of The Wildlife Society and the QCNR Student Council. During her time in The Wildlife Society, Trinity was recognized for Best Student Research Poster at the Utah chapter annual meeting. Throughout her academic career, Trinity was a recipient of several scholarships including the Aggie Scholar award and the Charles and Rae Perkins Scholarship. Trinity has been employed by the Nevada Department of Wildlife as a Conservation Aid working in fisheries for three field seasons. Trinity loves spending time outdoors, archery, and photography. Trinity hopes to continue finding fulfillment in outdoor adventures, and she will begin employment with the Nevada Department of Wildlife as a Conservation Aid immediately following graduation. Following this experience, Trinity hopes to gain field experience with different wildlife, especially sensitive species, and discover her research interests for graduate school and future employment.